

Intel® I/O Controller Hub 9 (ICH9) Family

Thermal and Mechanical Design Guidelines

— For the Intel® I/O Controller Hub 9 (ICH9) Desktop Family

June 2007



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Revision History

Rev. No.	Description	Date
-001	<ul style="list-style-type: none">Initial Release.	June 2007

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1 Introduction

The objective of thermal management is to ensure that the temperatures of all components in a system are maintained within functional limits. The functional temperature limit is the range within which the electrical circuits can be expected to meet specified performance requirements. Operation outside the functional limit can degrade system performance, cause logic errors, or cause component and/or system damage. Temperatures exceeding the maximum operating limits may result in irreversible changes in the operating characteristics of the component. The goal of this document is to provide an understanding of the operating limits of the Intel® ICH9 component.

As the complexity of computer systems increases, so do power dissipation requirements. The additional power of next generation systems must be properly dissipated. Heat can be dissipated using improved system cooling, selective use of ducting, and/or passive heatsinks.

The simplest and most cost-effective method is to improve the inherent system cooling characteristics of the ICH9 through careful design and placement of fans, vents, and ducts. When additional cooling is required, component thermal solutions may be implemented in conjunction with system thermal solutions. The size of the fan or heatsink can be varied to balance size and space constraints with acoustic noise.

This document presents the conditions and requirements to properly design a cooling solution for systems that implement the ICH9 component. Properly designed solutions provide adequate cooling to maintain the ICH9 component case temperature at or below thermal specifications. This is accomplished by providing a low local-ambient temperature, ensuring adequate local airflow, and minimizing the case to local-ambient thermal resistance. By maintaining the ICH9 component case temperature at or below maximum specifications, a system designer can ensure the proper functionality, performance, and reliability of this component.

Note: This document only applies to the desktop implementation of the Intel® ICH9 component.

Note: References to RAID in this document only apply to the Intel® 82801IR ICH9R I/O Controller Hub with RAID capabilities.



1.1 Terminology

Term	Description
mBGA	Mini Ball Grid Array. Smaller versions of the BGA and wire bonded package with die encased with a mold encapsulant.
T _C	The measured case temperature of a component. It is generally measured at the geometric center of the die or case, as specified in the component documentation.
T _{C-MAX}	The maximum case/die temperature.
T _{C-MIN}	The minimum case/die temperature.
TDP	Thermal Design Power is specified as the highest sustainable power level of most or all of the real applications expected to be run on the given product, based on extrapolations in both hardware and software technology over the life of the component. Thermal solutions should be designed to dissipate this target power level.
TIM	Thermal Interface Material: thermally conductive material installed between two surfaces to improve heat transfer and reduce interface contact resistance.
LFM	Linear Feet per Minute. Units of airflow velocity.
PTC	Package Thermal Capability. The maximum power level at which the component does not require a heatsink under the reference boundary condition assumptions.
Theta_CA	Thermal Resistance described using power dissipated between two points. Here, theta_ca is defined as: $(T_c - T_{ambient}) / (Power_{CA})$

1.2 Reference Documents

Document	Comments
Intel® Core™2 Duo Desktop Processor, Intel® Pentium® Dual Core Processor, and Intel® Pentium® 4 Processor 6x1 [^] Sequence	www.intel.com/design/processor/designex/313685.htm
Intel® I/O Controller Hub 9 (ICH9) Family Datasheet	www.intel.com/design/chipsets/datashts/316972.htm
Various System Thermal Design Suggestions	http://www.formfactors.org



2 Product Specifications

2.1 Package Description

The ICH9 component is available in a 676 ball, 31 mm square mBGA package shown in Figure 6 in Appendix B. The die size is 8.19 mm [0.323in] x 7.91 mm [0.311in].

2.2 Package Loading Specifications

Table 1 provides static load specifications for the ICH9 package. This mechanical maximum load limit should not be exceeded during heatsink assembly, shipping conditions, or standard use condition. Also, any mechanical system or component testing should not exceed the maximum limit. The chipset package substrate should not be used as a mechanical reference or load-bearing surface for the thermal and mechanical solution.

Table 1. Package Loading Specifications

Parameter	Maximum	Notes
Static	15 lbf	1,2,3

NOTES:

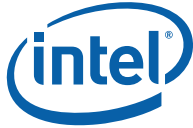
1. These specifications apply to uniform compressive loading in a direction normal to the chipset package
2. This is the maximum force that can be applied by a heatsink retention clip. The clip must also provide the minimum specified load on the ICH package for the thermal interface material.
3. These specifications are based on limited testing for design characterization. Loading limits are for the package only.

2.3 Thermal and Power Specifications

To ensure proper operation and reliability of the ICH9 component, the case temperature (T_C) must be at or below the maximum value T_{C-MAX} specified when dissipating TDP power listed in Table 2. The specifications define five configurations with slightly different requirements, which represent the expected usage of the ICH9 component on desktop motherboards. Configuration 3 is the configuration used for the Intel reference thermal solution analysis and design.

Note: The T_{C-MAX} specification is a requirement for sustained power dissipation equal to TDP. When the component is dissipating less than TDP, the case temperature must be maintained at temperatures less than T_{C-MAX} .

The actual ICH9 power dissipation is dependent on various factors including: system configuration, bandwidth & utilization of the available and connected ports, the component temperature & voltage and part-to-part variance. The TDP values assume



the part is operating at the TDP power dissipation and maximum case temperature and operating voltage.

Table 2. Intel® ICH9 Thermal Configurations and Power Specifications

Configuration		1	2	3	4	Energy Star Configuration
Devices	DMI x4	X4	X4	X4	x4	x4
	PCI	3	3	3	3	0
	PCI Express*	Two x1 s	Two x1 s	Two x1 s	One each x4 and x1	0
	LAN		Gigabit LAN Connect Interface (GLCI)	GLCI	GLCI	GLCI
	SATA ²	4	4	6	6	3
	USB (HS/FS) ¹	10/2	10/2	10/2	10/2	0/2
	HD Audio	Yes	Yes	Yes	Yes	Yes
T _{C-MAX} – with heatsink		100 °C	100 °C	97 °C	96 °C	
T _{C-MAX} – without heatsink ⁶		113 °C	113 °C	110 °C	110 °C	
T _{C-MIN}		0 °C				
Configuration Based Power ³		3.4 W	3.7 W	4.0 W	4.3 W	
Idle Power		0.76	0.92	0.96	0.96	0.90 W

NOTES:

1. USB HS = USB 2.0 High Speed Device (480 MB/s), USB FS = USB 2.0 Full Speed Device (12 MB/s)
2. 4 devices assume RAID 5 with 3 hard drives (3 GB/s) and 1 optical drive (1.5 GB/s) 6 devices assumes RAID 5 with 4 hard drives (3 GB/s) and 2 optical drives (1.5 GB/s)
3. The number of devices refers to both the number of ports supported on the board as well as the quantity of devices attached. Any port not routed to a connector is assumed to be functionally disabled according to Intel guidelines.
4. Configuration 3 is the configuration for Thermal Design Power and is the target for the Intel reference design.
5. The Idle power references ICH9 core and I/O interfaces idle with all low power features enabled. For Energy Star Configuration idle power, though there is no PCI Express and PCI devices connected, PCI Express and PCI are not functionally disabled.
6. Without a heatsink, most of the heat dissipated by ICH9 goes through the PCB, with the PCB acting as a heat spreader and then into the ambient air. When a heatsink is installed on the package, more power is now being pulled through the case. As a result the maximum case temperature must be maintained at lower level than without a heatsink to remain within specification.

The ICH9 package has a molded plastic encapsulant, and because plastic is such a poor heat conductor, the relative importance of the motherboard heat transfer characteristics increases. The heat transfer capability of the motherboard in the area of the ICH should be characterized. Knowledge of these heat transfer paths can be used to determine if an ICH heatsink is required.



In addition, high power PCI Express* graphic cards may alter the local ambient temperature as well as the airflow patterns in the vicinity of the chipset. Systems that have interface utilization less than that of the TDP configuration may be at power levels that may not require a heatsink.

In conclusion, thermal validation should be performed in your anticipated system environment, in particular measuring the ICH9 case temperature to ensure it does not exceed its maximum case temperature specification. To evaluate the capability of your system for cooling the ICH9, the following system level tests are suggested to assess ICH9 case temperature compliancy:

1. Shipping configuration(s) with expected end user add-in cards and I/O peripherals installed.
2. All available slots and IO ports populated (only worst case if all I/O is fully populated including SATA, USB, etc.).

For completeness, both room ambient conditions (approximately 23 °C, to simulate impact of fan speed control) and worse case maximum external temperature (35 °C) conditions should be considered in the validation test suite. If the ICH9 case temperature is above the published Tc-max – without heatsink in any test scenario, a heatsink is required.

If you determine that the ICH9 package requires a heatsink in your system configuration, please refer to Appendix A for the reference ICH9 heatsink vendor information.

2.4 T_{CONTROL} Limit

Intel® Quiet System Technology (Intel® QST) monitors an embedded thermal sensor. The maximum operating limit when monitoring this thermal sensor is T_{CONTROL}. For the Intel® ICH9 family this value has been defined as 101°C. This value should be programmed into the appropriate fields of Intel QST as the maximum sensor temperature for operation of the Intel ICH9 family

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3 Thermal Metrology

The system designer must make temperature measurements in order to accurately determine the thermal performance of the system. Intel has established guidelines for measuring chipset component case temperatures.

3.1 Case Temperature Measurements

To ensure functionality and reliability, the chipset component is specified for proper operation when T_C is maintained at or below the maximum temperature listed in Table 2. The surface temperature at the geometric center of the mold encapsulant corresponds to T_C . Measuring T_C requires special care to ensure an accurate temperature measurement.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce error in the measurements. The measurement errors could be due to a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation and/or convection, and/or conduction through thermocouple leads. To minimize these measurement errors, the approach described below titled 0° Angle Thermocouple Attach Methodology is recommended.

3.2 0° Angle Thermocouple Attach Methodology

1. Mill a 3.3 mm [0.13 in] diameter hole centered on bottom of the heatsink base. The milled hole should be approximately 1.5 mm [0.06 in] deep.
2. Mill a 1.3 mm [0.05 in] wide slot, 0.5 mm [0.02 in] deep, from the centered hole to one edge of the heatsink. The slot should be in the direction parallel to the heatsink fins (see Figure 2).
3. Attach thermal interface material (TIM) to the bottom of the heatsink base.
4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cutouts should match the slot and hole milled into the heatsink base.
5. Attach a 36 gauge or smaller calibrated K-type thermocouple bead or junction to the center of the top surface of the case using high thermal conductivity cement. During this step, make sure no contact is present between the thermocouple cement and the heatsink base because any contact will affect the thermocouple reading. It is critical that the thermocouple bead makes contact with the case (see Figure 1).
6. Attach heatsink assembly to the ICH, and route thermocouple wires out through the milled slot.

Figure 1. 0° Angle Attach Methodology (top view, not to scale)

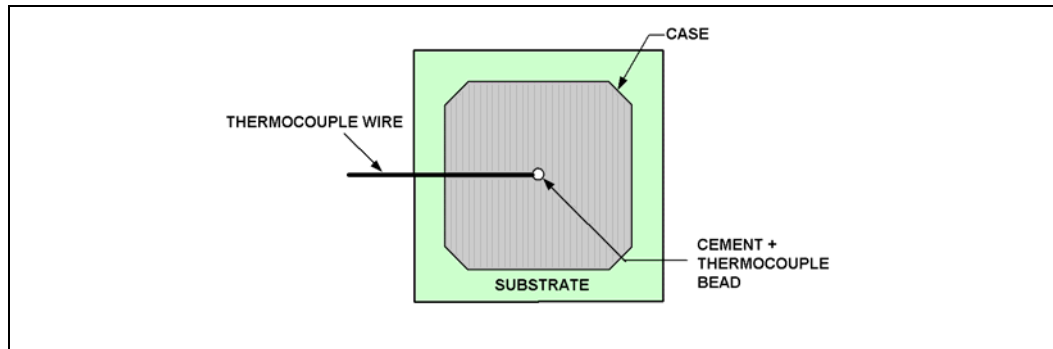
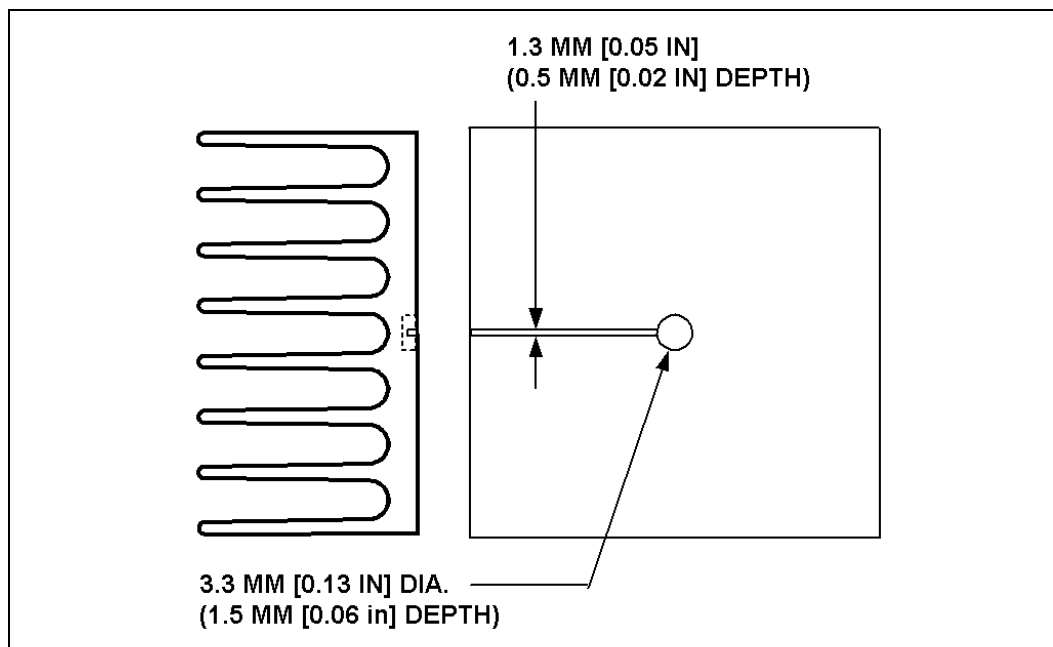


Figure 2. 0° Angle Attach Heatsink Modifications (generic heatsink shown, not to scale)



3.3 Ambient Temperature and Airflow Measurement

Figure 3 describes the recommended location for air temperature measurements measured relative to the component. For a more accurate measurement of the average approach air temperature, Intel recommends averaging temperatures recorded from two thermocouples spaced about 25 mm [1.0 in] apart. Locations for both a single thermocouple and a pair of thermocouples are presented.

Airflow velocity should be measured using industry standard air velocity sensors. Typical airflow sensor technology may include hot wire anemometers.

Figure 4 provides guidance for airflow velocity measurement locations. These locations are for a typical JEDEC test setup and may not be compatible with all chassis

layouts due to the proximity of the processor to the ICH, PCI and PCI Express* add-in cards. The user may have to adjust the locations for a specific chassis. Be aware that sensors may need to be aligned perpendicular to the airflow velocity vector or an inaccurate measurement may result. Measurements should be taken with the chassis fully sealed in its operational configuration to achieve a representative airflow profile within the chassis.

Figure 3. Recommended Temperature Measurement Placement: Top View

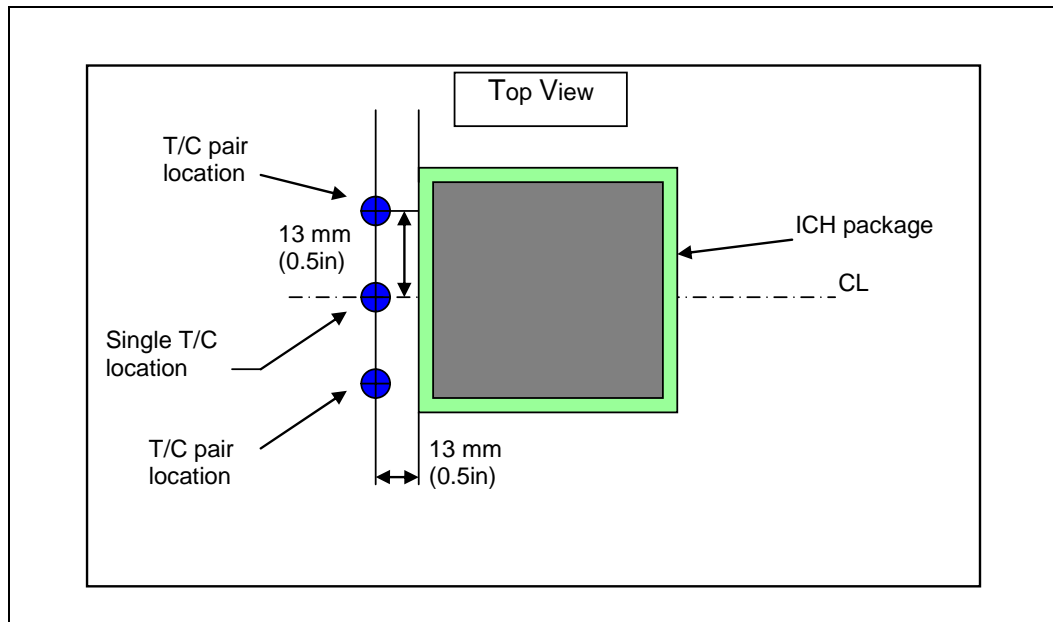
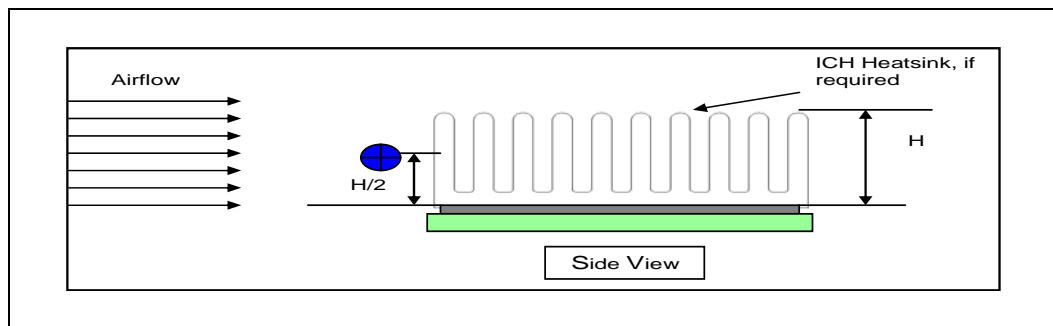


Figure 4. Recommended Airflow and Temperature Placement: Side View



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4 *ATX Reference Thermal Solution*

The ICH9 reference solution for an ATX platform assumes a component local operating environment as described in Section 4.2.

Using the TPD configuration (Config #3) given in Table 2, the ICH9 component requires an attached heatsink to meet thermal specifications. The local-ambient conditions are based on a 35 °C external-ambient temperature at sea level, where external-ambient refers to the environment external to the system. Refer to Appendix A for enabled suppliers for the reference thermal solution and Appendix B for reference thermal solution mechanical drawings.

Note: The reference heatsink for the ICH9 is the same reference heatsink originally developed Intel® ICH6 which was also used for the Intel® ICH7 and Intel® ICH8.

Refer to Figure 7 for reference ATX/μATX motherboard keep-out information. Heatsink can be tape-attached, or attached with a Z-clip. The motherboard keep-out allows for a Z-clip heatsink attach.

Note: Intel has not completed nor plans to perform thermal or mechanical validation with a tape-attached heatsink solution.



4.1 Environmental Reliability Requirements

If an attached heatsink is implemented the reliability requirements in Table 3 are recommended. The mechanical loading of the component may vary depending on the heatsink, and attach method used. The user should define validation tests based on the anticipated use conditions and resulting reliability requirements.

Table 3. Reference Thermal Solution Environmental Reliability Requirements

Test ¹	Requirement	Pass/Fail Criteria ²
Mechanical Shock	<ul style="list-style-type: none">• 3 drops for + and - directions in each of 3 perpendicular axes (i.e., total 18 drops).• Profile: 50 G trapezoidal waveform, 11 ms duration, 170 inches/sec minimum velocity change.• Setup: Mount sample board on test fixture.	Visual\Electrical Check
Random Vibration	<ul style="list-style-type: none">• Duration: 10 min/axis, 3 axes• Frequency Range: 5 Hz to 500 Hz• Power Spectral Density (PSD) Profile: 3.13 g RMS	Visual/Electrical Check
Thermal Cycling	<ul style="list-style-type: none">• -40 °C to +85 °C, 1000 cycles	Visual Check
Temperature Life	<ul style="list-style-type: none">• 85 °C, 1000 hours total	Visual/Electrical Check
Unbiased Humidity	<ul style="list-style-type: none">• 85 % relative humidity / 55 °C, 1000 hours	Visual Check

NOTES:

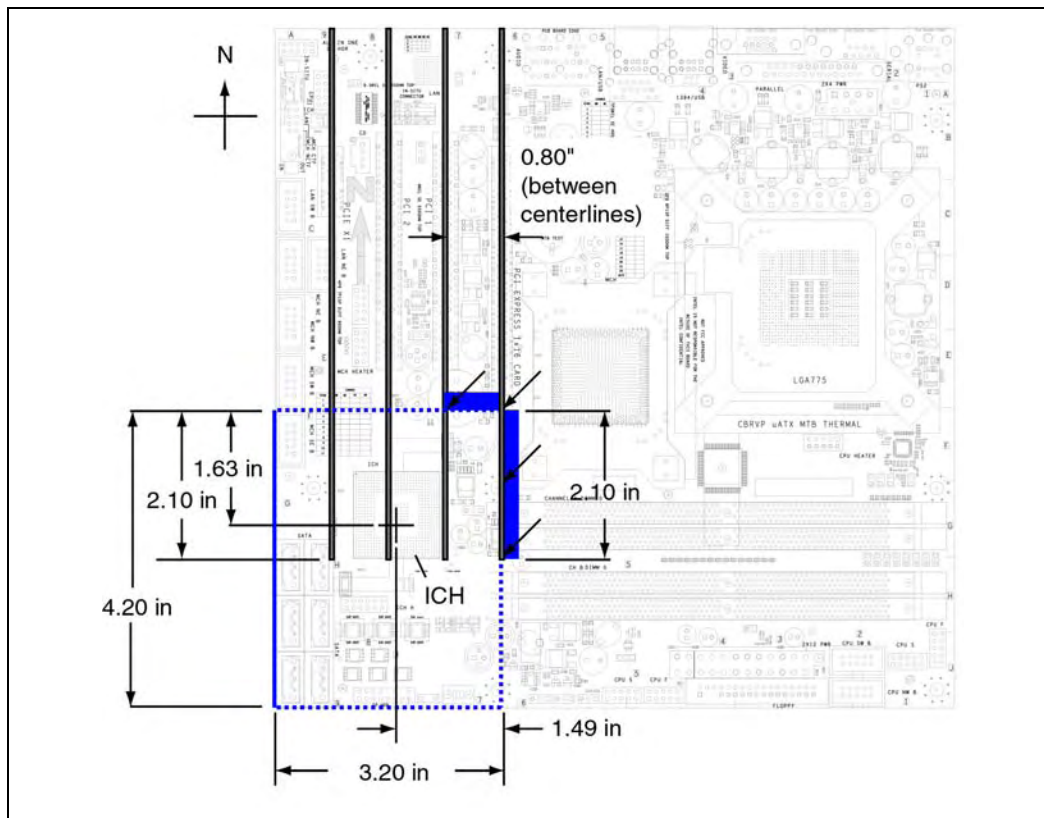
1. The above tests should be performed on a sample size of at least 12 assemblies from 3 different lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.

4.2 ATX boundary conditions

Intel's reference boundary conditions for ICH9 in an ATX system are 60°C inlet ambient temperature and 0.25m/s [50 lfm] of airflow. See Figure 5 for more details on the ATX boundary conditions.

In the ATX boundary conditions listed above, the ICH9 will not require a heatsink when power dissipation is at or below 2.7 W. This value is referred to as the Package Thermal Capability, or PTC. Note that the power level at which a heatsink is required will also change depending on system local operating ambient conditions and system configuration.

Figure 5. ATX Boundary Conditions

**NOTES:**

1. Airflow is entering at 45° angle (see arrows) at 50 LFM at 60°C – through the two shaded boxes shown.
The assumed opening is 0.63 x 0.80 inches on the north face and 0.63 x 2.10 inches on the east face.
2. Airflow condition boundary box (blue dashed lines):
West face completely blocked by chassis wall.
East face aligned with the graphics card.
North, South and East faces open except for add-in card obstructions.
The add-in cards have a 0.63 inch gap from the motherboard to the card bottom edge.
3. Motherboard thickness 0.062 inches with 0.25 gap below board.

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5 *Balanced Technology Extended (BTX) Thermal Solution Guidance*

In BTX systems the Thermal Module Assembly (TMA) is the primary fan in the system. A set of three system level boundary conditions have been established to determine ICH thermal solution requirement.

- High ambient / TDP for the components (Case 1). This covers the maximum TMA fan speed condition.
- Low external ambient / TDP for the components (Case 2). The TMA fan speed is limited by the thermistor in the fan hub.
- Low external ambient / Low power for the components (Case 3). This covers the system idle acoustic condition

In addition to the 3 cases listed above the analysis will review two chassis configurations to determine the worst case

- Small Form Factor Entertainment PC (EPC) with the Type II 65 W TMA developed for the Intel® Core™2 Duo Processors. See *Intel® Core™2 Duo Desktop Processor Thermal Mechanical Design Guidelines (TMDG)* for details on the reference thermal design.
- BTX Tower System with a Type I TMA optimized for 65 W processor power.

Current design analysis indicates the Small Form Factor Entertainment PC (EPC) is the limiting thermal condition for Case 2 and 3 (see Table 4).

Table 4. Projected Chassis Conditions by Case for BTX Form Factor

Case	T _A above motherboard (°C)	Airflow above motherboard (LFM)	T _A below motherboard (°C)	Airflow below motherboard (LFM)	PTC (W)
Case 1	51.3	91.3	57.8	52.8	4.8
Case 2	56.5	47.5	79.4	29.9	4.0
Case 3	55.9	10.9	71.7	15.4	2.9

NOTES:

1. PTC is Package Thermal Capability which is a measure of the power that can be dissipated without a thermal solution.



The customer should analyze their system design to verify the boundary conditions prior to design.

For example, the local inlet ambient air for the ICH9 component in a BTX system is projected to be approximately 55 °C to 60 °C.

The analysis of the ICH cooling should account for the airflow above and below the motherboard. Without a heatsink the ICH package will dissipate a significant portion of the heat into the motherboard.

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Appendix A Currently Enabled Suppliers

The currently enabled suppliers for the Reference thermal solution supporting the ICH6, ICH7, ICH8 and ICH9 are listed in Table 5.

Table 5. Enabled Suppliers for the Intel® ICH6, ICH7, ICH8 & ICH9 Reference Heatsink

Supplier	Intel Part Number	Vendor Part Number	Contact Information
AVC * (Asia Vital Components)	C46655-001	S702C00001	Taiwan: David Chao - +886 (-2) -2299-6930 x7619 Email: david_chao@avc.com.tw Taiwan: Raichel Hsu +886 (-2) -2299-6930 x7630 raichel_hsi@avc.com.tw
CCI* (Chaun-Choung Technology Corp.)	C46655-001	00C855802B	Taiwan: Monica Chi Email: monica_chih@ccic.com.tw Tel: +886 - 2 -2995-2666 Ext 131 USA: Harry Lin Email: hlinack@aol.com Tel: (714) 739-5797
Foxconn*	C46655-001	2Z802-009	USA: Jack Chen, PH.D Email: jack.chen@foxconn.com Tel: (408) 919-6121 USA: Wanchi Chen Email: wanchi.chen@foxconn.com Tel: (408) 919-6135

NOTES: These vendors and devices are listed by Intel as a convenience to Intel's general customer base, but Intel does not make any representations or warranties whatsoever regarding quality, reliability, functionality, or compatibility of these devices. This list and/or these devices may be subject to change without notice.



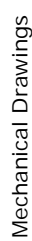
*Currently Enabled **Suppliers***



Appendix B Mechanical Drawings

The following table lists the mechanical drawings available in this document:

Drawing Name	Page Number
Intel® ICH9 Component Package Drawing	26
Motherboard Keep-Out for Reference Heatsink	27
Reference Heatsink Extrusion	28
Reference Heatsink Clip	29
Reference Heatsink Assembly	30



NOTES:

1. ALL DIMENSIONS AND TOLERANCES CONFORM TO ANSI Y14.5M-1982.
2. REFER TO INTEL REPRESENTATIVE FOR XY COORDINATES OF EXACT BALL LOCATION.
3. BGA SOLDER RESIST OPENING IS 470UM.

The drawing includes three views of a BGA package:

- TOP VIEW:** Shows a square package with overall dimensions of 31.00 ±0.10 on all sides. The mounting pad dimensions are 26.00 ±0.20. There are 4x 45° chamfers and 4x 1.91±0.2 dimensions for the mounting pads. A note specifies: "PIN #1 IS LOCATED 1.2 DIA. ± 0.15 TYP. 45° ± 0.5° FROM CENTER LINE".
- SIDE VIEW:** Shows the profile of the package with dimensions: 2.28 ±0.21, 1.17 ±0.05, 0.61 ±0.06, and 0.50 ±0.10. A note indicates "ALL AROUND".
- BOTTOM VIEW:** Shows the underside of the package with a grid of solder balls. Dimensions include 676x8, 0.70, 0.50, 1.425, 16.57, and 26.18. A note specifies "PIN #18 SEE P. 0000".

TOP VIEW

SIDE VIEW

BOTTOM VIEW

Figure 7. Motherboard Keep-Out for Reference Heatsink

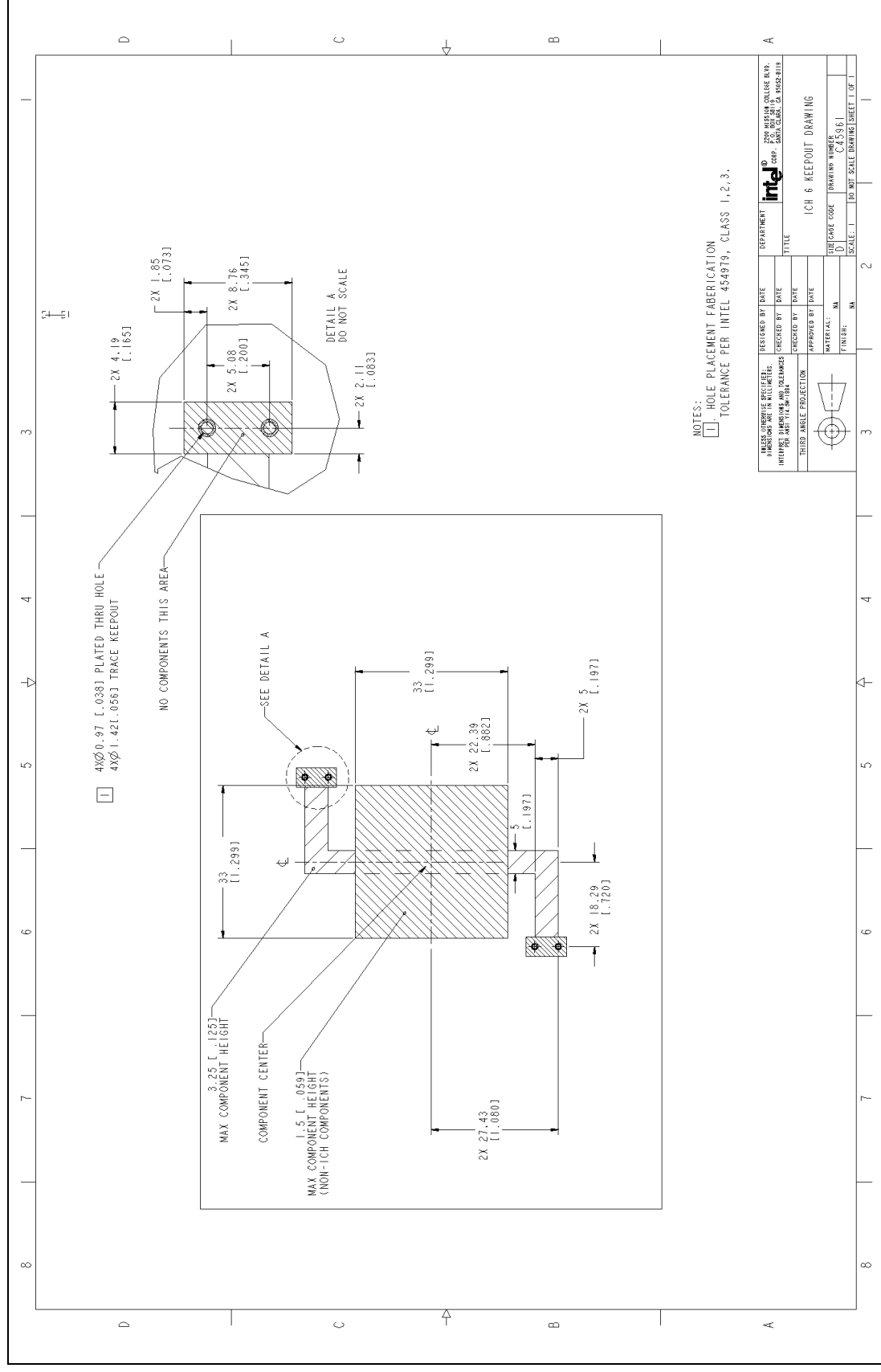




Figure 8. Reference Heatsink Extrusion

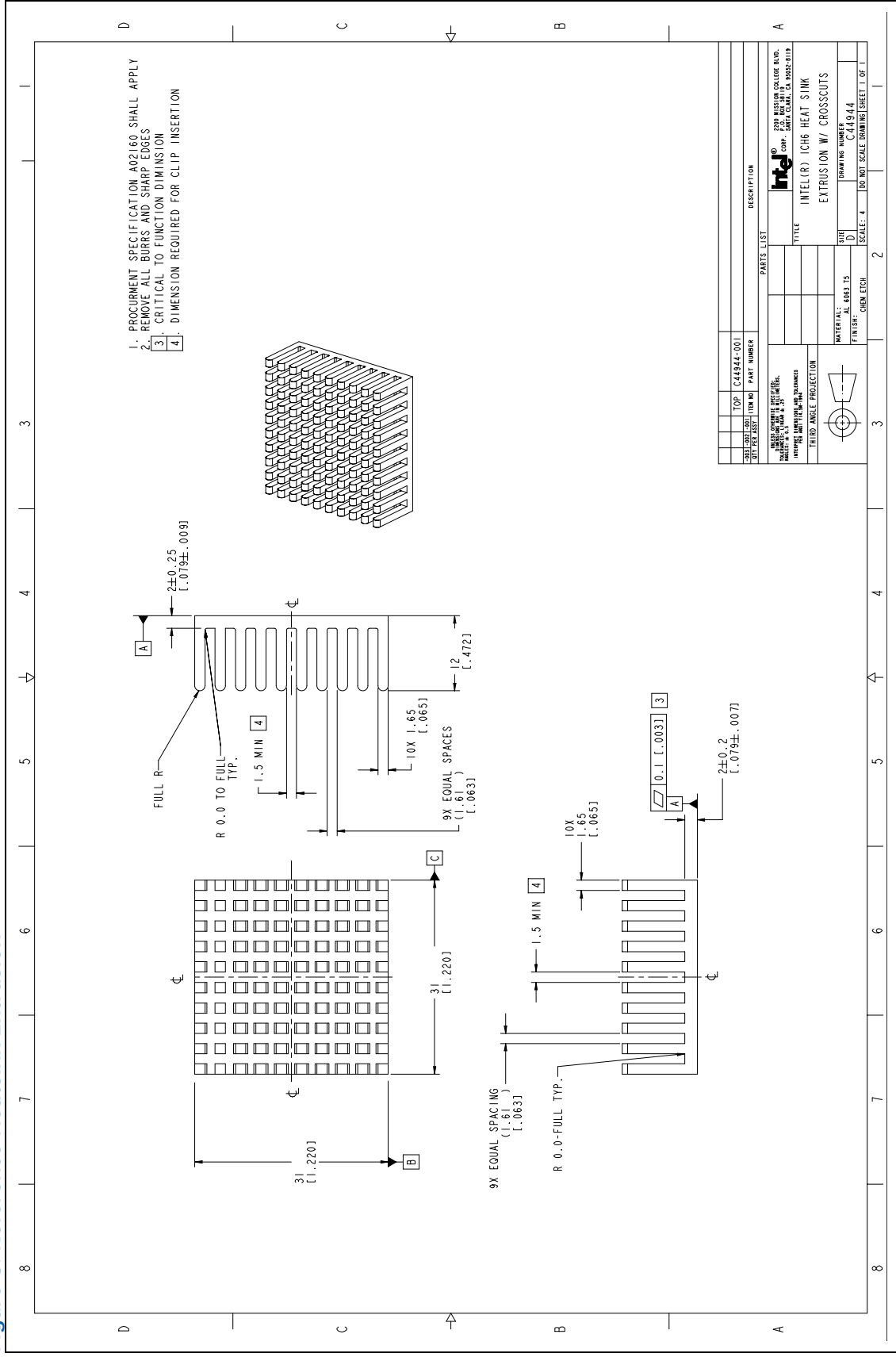
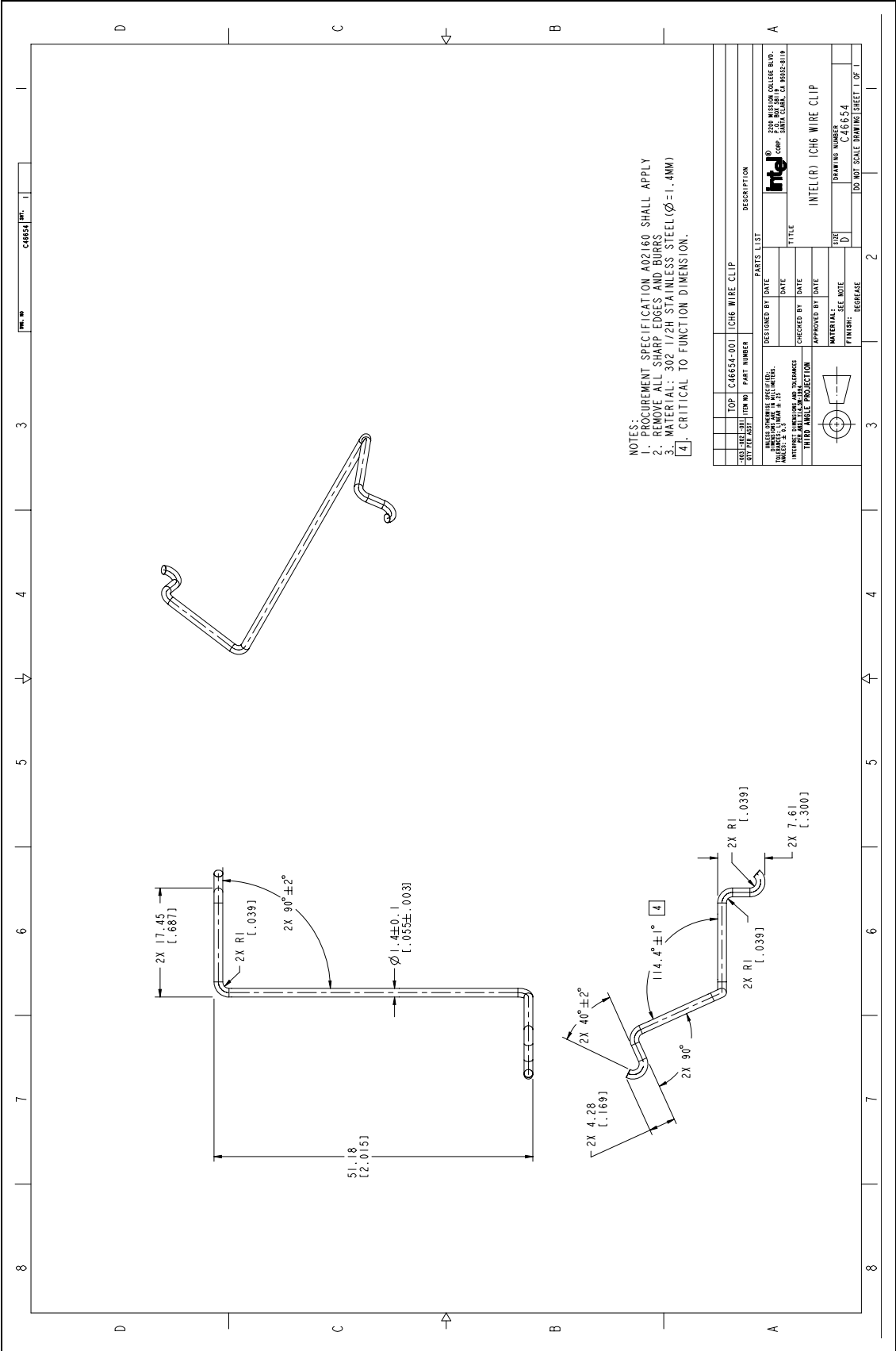




Figure 9. Reference Heatsink Clip



Technical drawing of the ICH6 Heat Sink Assembly. The drawing includes a top view (A) showing a square heat sink with a grid of pins, a side view (B) showing the profile of the pins, and a perspective view (C) showing the heat sink with three clips (1, 2, 3) attached. Dimensions are provided: 26 [1.024] for the width and height of the heat sink body. The drawing is labeled "ICH6 WIRE CLIP", "ICH6 HEAT SINK EXTRUSION W/CROSSCUTS", and "ICH6 HEAT SINK ASSEMBLY". The Intel logo is present, along with the text "22ND WILSON COLLEGE BLVD., MENLO PARK, CA 94025" and "C46-655".